IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

DENTAL MONITORING, Plaintiff, v. GET-GRIN INC., Defendant.	)	CASE NO.: 1:22-cv-00647-WCB CONSOLIDATED.

DECLARATION OF LINA KARAM PH.D. IN SUPPORT OF GET-GRIN'S ANSWERING CLAIM CONSTRUCTION BRIEF

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1. I, Lina Karam, have personal knowledge of the matters set forth herein and, if called as a witness, could and would competently testify thereto.

I. INTRODUCTION

2. I have been retained by Defendant Get-Grin Inc. ("Grin") as an expert in the above-captioned matter. My role is to provide my professional opinions with respect to the claim construction for U.S. Patent Nos. 11,314,983 ("the'983 patent"; D.I. 30-1, Ex. A) and 10,755,409 ("the'409 patent"; D.I. 30-1, Ex. B) (collectively, the "AI Patents") as well as the state of the art, background and prior art to the Asserted Patents.

II. QUALIFICATIONS

3. My qualifications are set forth in my curriculum vitae, a copy of which is attached as Appendix A to my declaration. As set forth in my curriculum vitae:

4. I received a Bachelor of Engineering (B.E.) from the American University of Beirut in Computer and Communications Engineering in 1989, and a M.S. and a Ph.D. from the Georgia Institute of Technology in Electrical Engineering in 1992 and 1995, respectively.

5. I am currently an Emerita Professor in the School of Electrical, Computer, and Energy Engineering at Arizona State University (ASU) and the Director of the R&D Image, Video, and Usability (IVU) Laboratory at ASU. Prior to becoming Emerita Professor, I was a tenured Full Professor, Computer Engineering Program Chair and Computer Engineering Director for Industry Engagement at ASU. From 2020 to 2022, I served as Dean of the School of Engineering at the Lebanese American University. From 2019 to 2021, I served as the Editor-In-Chief of the high-impact IEEE Journal of Special Topics in Signal Processing. I am also the President of PICARIS, LLC, a consulting company that provides expertise on media processing, compression, computer vision, and machine learning. I am also Chief Technical Advisor at AIAEC, LLC.

6. My research includes topics such as Signal, Image, and Video Processing, Compression, and Transmission; Computer Vision; Machine Learning; Perceptual-based Processing; Visual Attention Models; Automated Quality Assessment and Monitoring; Multidimensional Signal Processing; and Digital Filter Design. I have various awards in recognition of my research, including U.S. National Science Foundation CAREER Award, Intel Outstanding Researcher Award, U.S. National Aeronautics and Space Administration (NASA) Technical Innovation Award, the IEEE Signal Processing Society (SPS) Best Journal Paper Award, IEEE Phoenix Section Outstanding Faculty Award, and IEEE Region 6 Award. I am featured in the 8th and 9th editions of Research.com (2022 and 2023) among World Top Computer Science Scientists.

7. In addition, I am an Institute of Electrical and Electronics Engineers (IEEE) Fellow, which is the highest grade level conferred by IEEE each year to no more than one-tenth of 1% of all IEEE voting members, for my contributions in the areas of image and video processing, visual media compression and transmission, and digital filtering. In addition to serving as Editor-In-Chief of a prestigious IEEE journal, I have also served on several IEEE Boards and chaired multiple IEEE committees. For example, I served on the IEEE Signal Processing Society (SPS) Board of Governors (2016-2018), IEEE SPS Publications Board (2019-2021), IEEE SPS Award Board (2019-2020), IEEE SPS Conference Board (2003-2005 & 2017-2018), IEEE Publication Services and Products Board (PSPB) Strategic Planning Committee (2014-2016), IEEE Technical Activities Board (TAB)/PSPB Product and Services Committee, IEEE Educational Activities Board (EAB) Faculty Resources Committee, and IEEE TechRxiv Advisory and Editorial Boards. I am also an expert delegate of the ISO/IEC JTC1/SC29

Committee (Coding of audio, picture, multimedia, and hypermedia information) and participating in JPEG/MPEG standardization activities.

8. As part of my various roles at ASU, PICARIS, AIAEC, ISO and IEEE, I am actively involved in industry. For example, as an intern I contributed to the development of image and video processing and compression at AT&T Bell Labs (Murray Hill), and multi-dimensional data processing and visualization at Schlumberger. Later in my career I collaborated in the research and development of computer vision, machine learning, image/video processing, compression, and transmission projects with various industry leaders, including Intel, Qualcomm, Google, NTT, Motorola, Freescale, NXP, General Dynamics, and NASA. More recently, I took on the role of Chief Technical Advisor at AIAEC, LLC, supervising work and product development in the field of AI and machine learning.

9. In addition, I directed the development of image/video processing, compression, computer vision and machine learning technologies. The developed computer vision and machine learning systems for automated defect detection, 3D characterization, gender/age prediction, and autonomous vehicles were adopted at Intel. The developed image-based non-wet solder joints detection system was granted a Divisional Recognition Award by Intel. More details can be found in Said, Bennett, Karam, and Pettinato, "Automated Detection and Classification of Non-Wet Solder Joints," IEEE Transactions on Automation Science and Engineering, Jan 2011. The developed image-based automated void detection system helped in enabling two industry standards, JEDEC JC 14-1 void guideline and IPC-7095C. More details can be found in Said, Bennett, Karam, Siah, Goodman, and Pettinato, "Automated Void Detection in Solder Balls in the Presence of Vias and Other Artifacts," IEEE Transactions on Electronics Packaging Manufacturing, November 2012. More details about the developed 3D characterization system

including image-based solder ball height and warpage measurements can be found in Li, Bennett, Karam, and Pettinato, "Stereo Vision Based Automated Solder Ball Height and Substrate Coplanarity Inspection," IEEE Transactions on Automation Science and Engineering, April 2016, and in Karam and Li, "Stereo Vision Measurement System and Method," US Patent 9,704,232 B2, issued July 2017. Details about machine learning based computer vision for defect detection can be found in Haddad, Yang, Karam, Ye, Patel and Braun, "Multi-Feature, Sparse-Based Approach for Defects Detection and Classification in Semiconductor Units," IEEE Transactions on Automation Science and Engineering, August 2016, and in Haddad, Dodge, Yang, Karam, Ye, Patel and Braun, "Locally Adaptive Statistical Background Modeling with Deep Learning-Based False Positive Rejection for Defect Detection in Semiconductor Units," IEEE Transactions on Semiconductor Manufacturing, August 2020.

10. The developed machine learning and computer vision systems for autonomous vehicles include Advanced Driver Assist Systems (ADAS) technologies. The developed real-time forward collision warning system prototype was demonstrated by our Intel industry collaborators at the 2015 Consumer Electronics Show (CES) in Las Vegas. More details can be found in Prakash, Li, Akhbari, and Karam, "Sparse Depth Calculation using Real-time Key-point Detection and Structure from Motion for Advanced Driver Assist Systems," Springer Lecture Notes, ISVC, December 2014, and in Prakash, Akhbari, and Karam, "Robust Obstacle Detection for Advanced Driver Assistance Systems using Distortions of Inverse Perspective Mapping of a Monocular Camera," Robotics and Autonomous Systems Journal, 2019.

11. I directed the development of scalable visual compression technologies. The developed codecs, utilizing the scalable visual compression technologies, were commercialized by General Dynamics. More details can be found in Chien, Sadaka, Abousleman, and Karam,

"Region-of-Interest-Based Ultra Low-Bit-Rate Video Coding," SPIE Symposium on Defense & Security, March 2008. I also directed the development of perceptual-based visual compression methods and algorithms. The work on JPEG2000 Encoding with Perceptual Distortion Control enabled the integration of adaptive perceptual-based visual processing and compression in the JPEG 2000 image coding standard and demonstrated improved performance in terms of visual quality and compression, while maintaining full compatibility with the JPEG 2000 standard. For this perceptual-based image compression work, I received a Technical Innovation Award from NASA.

12. In addition, I directed the development of automated biomedical image processing and computer vision technologies that enable high-throughput cancer diagnostics and drug discovery. The developed automated image analysis technologies were licensed for cancer research at different industries and institutions, including the Translational Genomics Institute (TGEN) and the New York School of Medicine. More details can be found in Karam and Said, "Automatic Cell Migration and Proliferation Analysis," US Patent 9,082,164, issued July 2015.

13. My work has been published numerous times in prestigious journals, including the IEEE Transactions on Signal Processing, IEEE Transactions on Image Processing, IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI), IEEE Transactions on Broadcasting, and IEEE/CVF Computer Vision and Pattern Recognition (CVPR) Conference. Some selected publications include "Morphological Reversible Contour Representation," IEEE Transactions on Pattern Analysis and Machine Intelligence, March 2000, "Morphological Text Extraction from Images," IEEE Transactions on Image Processing," Nov. 2000, "A No-Reference Objective Image Sharpness Metric Based on the Notion of Just Noticeable Blur (JNB)," IEEE Transactions on Image Processing, April 2009, "Automated Detection and

Classification of Non-Wet Solder Joints," IEEE Transactions on Automation Science and Engineering, Jan. 2011, "Objective Video Quality Assessment Methods: A Classification, Review, and Performance Comparison," IEEE Transactions on Broadcasting, June 2011, "An Efficient Selective Perceptual-Based Super-Resolution Estimator," IEEE Transactions on Image Processing, Dec. 2011, "Select Trends in Image, Video, and Multidimensional Signal Processing," IEEE Signal Processing Magazine, Jan. 2012, "A Distributed Canny Edge Detector: Algorithm and FPGA Implementation," IEEE Transactions on Image Processing, July 2014, "3D Blur Discrimination," ACM Transactions on Applied Perception, May 2016, "Spatially-Varying Blur Detection Based on Multiscale Fused and Sorted Transform Coefficients of Gradient Magnitudes," IEEE Conference on Computer Vision and Pattern Recognition (CVPR), July 2017, "Unconstrained Ear Recognition using Deep Neural Networks," IET Biometrics, January 2018, "Visual Saliency Prediction Using a Mixture of Deep Neural Networks," IEEE Transactions on Image Processing, August 2018, "Quality Robust Mixtures of Deep Neural Networks," IEEE Transactions on Image Processing, November 2018, "Augmented Sparse Representation Classifier (ASRC) for Face Recognition under Quality Distortions," IET Biometrics Journal, November 2019, "DeepCorrect: Correcting DNN Models against Image Distortions," IEEE Transactions on Image Processing, December 2019, "It GAN DO Better: GAN-based Detection of Objects on Images with Varying Quality," IEEE Transactions on Image Processing, November 2021. I also co-authored a machine learning book entitled "Introduction to Machine Learning and Deep Learning: A Hands-On Starter's Guide," published in 2017, revised in 2019, and available online at https://deeplearningtextbook.org/.

14. I am an inventor, and I have been awarded eight patents in the field of image and video processing, compression, transmission, computer vision, and machine learning: U.S. Patent

Nos. 6,154,493 ("The Compression of Color Images Based on a 2-Dimensional Discrete Wavelet Transform Yielding a Perceptually Lossless Image"), 6,124,811 ("Realtime Algorithms and Architectures for Coding Images Compressed by DWT-Based Techniques"), 6,717,990 ("Communication System and Method for Multi-Rate, Channel-Optimized Trellis-Coded Quantization"), 7,551,671 ("System and Method for Transmission of Video Signals using Multiple Channels"), 9,082,164 ("Automatic Cell Migration and Proliferation Analysis"), 9,501,710 ("Systems, Methods, and Media for Identifying Object Characteristics Based on Fixation Points"), 9,704,232 ("Stereo Vision Measurement System and Method"), and 11,0304,85 ("Systems and Methods for Feature Corrections and Regeneration for Robust Sensing, Computer Vision, and Classification,"). I was also a named inventor on an additional patent application, published as U.S. 2008/0259796 ("Method and Apparatus for Network-Adaptive Video Coding").

15. Additional information regarding my background, qualifications, publications, and presentations is provided in my curriculum vitae, which is attached as Appendix A.

III. COMPENSATION

16. I am being compensated for my time at my usual and customary hourly rate. My compensation is not contingent upon my performance, the opinions or conclusions I reach in my analysis, or the outcome of the above-identified matter. I also have no financial interest in Grin or this litigation.

IV. LEGAL PRINCIPALS

17. I am informed by counsel that the following legal standards are applicable to the issues I address in this declaration and have relied on these standards in this declaration.

18. I understand that a patent includes a written description that has a "specification" and "claims." I further understand that the applicable patent law requires that the specification

shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as the invention.

19. I understand that claim construction is the process in which courts interpret the meaning and scope of a patent's claims. I further understand that the general principle of claim construction is that words of a claim are generally given their ordinary and customary meaning, which is the meaning that the term would have to a person of ordinary skill in the art in question at the time of the invention.

20. I address the level of ordinary skill in the art in Section V of my declaration, below. I understand that, to ascertain the meaning of a claim term, the court will look to those sources available to the public that show what a person of ordinary skill in the art would have understood disputed claim language to mean.

21. I understand that claim construction is viewed from the standpoint of a hypothetical person of ordinary skill in the art and what that hypothetical person would understand from the claims, specification, and file history. I understand that this process involves determining the level of skill in the art at the time the invention was made, because the hypothetical person of ordinary skill in the art is deemed to have that level of skill. I further understand that a person of ordinary skill in the art is presumed to have known the relevant art at the time of the invention.

22. I understand that the claims, specification, and file history are referred to as intrinsic evidence and that such intrinsic evidence is highly relevant and often the best guide to claim construction. I understand that other evidence, such as expert testimony, prior art, contemporaneous dictionaries or references, may be considered and that such evidence is referred

to as extrinsic evidence. I further understand that extrinsic evidence may not be used to contradict the intrinsic evidence.

23. It is my understanding that the claims of a patent define the scope of the invention. Further, claims must be read in view of the specification, of which they are a part. The construction of any terms in the claim should not expand the scope of any claims.

24. It is also my understanding that arguments and amendments made during the prosecution of a patent application and other aspects of the prosecution history, as well as the specification and other claims, must be examined to determine the meaning of terms in the claims. In particular, the prosecution history (or file wrapper) limits the interpretation of claims so as to exclude any interpretation that may have been disclaimed or disavowed during prosecution in order to obtain claim allowance. I understand that beyond the notice function and reliance-based aspects of a patent's prosecution history, the prosecution history provides evidence of how the Examiner at the USPTO and the inventor understood the patent.

25. I understand that while a court may look to extrinsic evidence such as dictionaries, the intrinsic record, which includes how the patentee described the invention to the Patent Office during prosecution, controls. The prosecution history may demonstrate that the patentee intended to deviate from a term's ordinary and accustomed meaning. I understand that the Federal Circuit has held that dictionary definitions are of secondary importance when construing claims and that the intrinsic evidence, which includes the claim language, patent specification, and prosecution history, should be consulted first.

26. I understand that intrinsic evidence also includes references cited during prosecution of the patent, and it also includes the references cited on the face of the patent.

V. PERSON OF ORDINARY SKILL IN THE ART

27. I have been informed that the relevant timeframe for assessing the level of skill of a person of ordinary skill in the art ("POSA") is around July 2017, which is the earliest priority date published on the face of the '983 and '409 patents.

28. It is my opinion that the POSA for the AI Patents would have a bachelor's degree or higher in computer science, bioinformatics, electrical engineering, computer engineering, or a related engineering discipline, and several years of work experience relating to the development of machine learning or artificial intelligence models for image processing and/or computer vision.

29. I am at least a POSA because I have a Ph.D. in electrical engineering and over a decade of work experience relating to the development of machine learning or artificial intelligence models for image processing and/or computer vision.

VI. OVERVIEW OF AI PATENTS

30. The AI Patents generally relate to methods of analyzing an image of a dental arch, and more particularly to analyzing an image using a deep learning device to determine an attribute value of a tooth represented in the image or an attribute value of the image. *See* '983 patent at 1:22-28. The deep learning device is trained on a set of images known as a learning base. *Id*. at 3:14-18. The AI Patents teach that an analysis image may be captured using a cell phone. *Id*. at 18:59-64. Further, the capturing of the image may be performed by a patient. *Id*. at 9:9-13. The analysis image is submitted to the trained deep learning device wherein the deep learning device recognizes patterns and, based on these patterns, determines at least one probability relating to the considered attribute value, *i.e.*, attribute value of a tooth represented in the image or attribute value of the image. *Id*. at 16:56-64, 17:40-44.

VII. OPINIONS ON CLAIM CONSTRUCTIONS

31. I understand from Grin's counsel that there is a dispute over the scope of the claims and that claim construction is required when there is a dispute over claim scope.

32. I have been asked to provide my opinions for the following terms from the AI Patents: "deep learning device," "neural network" and "creation of a learning base."

33. I have reviewed Grin's constructions for the terms "deep learning device," "neural network" and "creation of a learning base" from the AI Patents, and it is my opinion that they are consistent with the understanding of a POSA at the time of the alleged inventions in view of the AI Patents, their file histories, and the evidence—both intrinsic and extrinsic—including the evidence cited in the parties' Amended Joint Claim Construction Chart (D.I. 72). In my opinion, Grin's proposed constructions, which are consistent with the intrinsic evidence, including the claims, specification, figures and patent file histories, will aid the jury by providing clarity and the correct understanding of the claim terms for determining the infringement and validity issues in this case.

34. I have reviewed Dental Monitoring's (DM's) proposed constructions and disagree with DM's constructions because they are inconsistent with the understanding of a POSA at the time of the alleged inventions in view of the AI Patents, their file histories, and the evidence—both intrinsic and extrinsic.

35. The extrinsic evidence consists at least of dictionaries and technical papers that are contemporaneous with the time of the alleged invention (i.e., 2017) for the AI Patents.

A. Deep Learning Device

Term	Dental Monitoring's Construction	Get-Grin's Construction
Deep learning device '983 Patent claims 1, 2, 3, and 12 '409 Patent claims 1, 3, 7, and 15	A device that, through training, is capable of analyzing an image and recognizing patterns therein.	A device that employs a deep neural network to classify data after being trained on an input dataset

1. A "Deep Learning Device" Employs A Deep Neural Network

36. In my opinion, a POSA at the time of the alleged invention for the AI Patents would have understood the term "deep learning device" to mean "a device that employs a deep neural network to classify data after being trained on an input dataset." This construction is supported by the claims, specification, the knowledge of a POSA as well as the extrinsic evidence.

37. Grin's proposed construction is consistent with the claim language. A POSA would understand that the AI Patent claims show that the "deep learning device" uses a neural network. For example, claim 1 of the '983 patent" recites, in part "***submission of the analysis image to a neural network***, … said method also comprising the following steps: … B) training of at least one deep learning device, by means of the learning base; C) ***submission of the analysis image to said at least one deep learning device***." '983 patent at 32:29-44.[1] A POSA would understand from this that the method of submitting the image to a neural network is accomplished by submitting the image to a deep learning device that uses a neural network. *Id.*

[1] All emphasis herein is added, and all internal citations and quotations are omitted unless otherwise noted.

38. Grin's proposed construction is also consistent with the specification and intrinsic evidence. A POSA would understand that the specification consistently associates "deep learning" with "neural networks." *See, e.g.*, '983 patent, at 1:24-25.

39. A POSA also would understand that a deep learning device can include additional functionality beyond the neural network, but it is never without a neural network. For example, the patent specification consistently states that the deep learning device is "preferably a neural network" (for example, '983 patent at 1:24-25, 1:39-40, 16:13-14). A POSA would understand the language "preferably a neural network" to indicate an embodiment of the invention where the deep learning device is a neural network without additional functionality.

40. In addition, a POSA would understand from the File History and References Cited on the face of the AI patents that the "deep" in "deep learning device" refers to a neural network and/or to a device that employs a neural network. In the Notice of Allowance for the '983 patent, the Examiner wrote "[t]his invention relates generally, to a method for analyzing an image, called 'analysis image', of a dental arch of a patient, a method in which the analysis image is submitted to a ***deep neural network,*** in order to determine at least one value of a tooth attribute relating to a tooth represented on the analysis image." Ex.[2] 1 at DENTAL647_00017617.

41. Likewise, a review of the references titles cited on the face of the AI Patents show that deep learning requires a deep neural network—"Detection and Classification of Dental Caries in X-ray Images Using ***Deep Neural Networks***" by Ben Ali Ramzi et al. and "Tooth labeling in cone-beam CT using ***deep convolutional neural network*** for forensic identification" by Miki Yuma et al. *See* '983 patent at 2; *see also*'409 patent at 2. A POSA would understand

[2] "Ex." refers to exhibits in support of Grin's Answering Claim Construction Brief.

from this intrinsic record that the AI patents use the term "deep learning device" consistent with its ordinary meaning, which a POSA would understand requires use of a deep neural network.

42. With respect to the extrinsic evidence, it is my opinion that it overwhelmingly supports that the deep learning device employs neural networks. *See, e.g.*, Ex. 2 (Meriam-Webster: "In deep learning, multiple ***neural networks are 'stacked' on top of each other, or layered***…."); Ex. 3 (Dictionary.com: Deep Learning is "an advanced type of machine learning that ***uses multilayered neural networks***...."); Ex. 4 (HP Glossary: "Neural networks drive deep learning"); Ex. 5 (IBM Glossary: "Deep learning is a subset of machine learning, which ***is essentially a neural network*** with three or more layers."); Ex. 6 (Oracle Glossary: "Deep learning is a subset of machine learning (ML), ***where artificial neural networks—algorithms modeled to work like the human brain—learn from large amounts of data***."). A POSA would understand that the definition of deep learning has not changed since the time of the invention of the AI Patents.

43. I understand DM argues that the deep learning device is not limited to using a neural network because dependent claim 15 of the '409 patent recites "[t]he method as claimed in claim 1, in which ***the deep learning device is a neural network***." Plaintiff's Op. Claim Construction Brief ("DM Brief") at 4-5 (citing '409 patent, claim 15). I disagree because a POSA would have understood the language of claim 15, which states that the deep learning device ***is*** a neural network, to be different from Grin's construction, which states, that a "deep learning device" is "a device that ***employs a deep neural network*** to classify data after being trained on an input dataset." Claim 15 equates the deep learning device with a neural network whereas Grin's construction states that the deep learning device employs (i.e., uses) a neural network. A POSA would understand that a deep learning device that employs a neural network, as described

in claim 1, could contain functionality in addition to the neural network. By contrast, a POSA would also understand that a deep learning device that ***is*** a neural network, as described in claim 15, is limited to a neural network.

44. A POSA would understand that the use of a neural network, specifically a deep neural network, is an essential requirement of a deep learning device. A POSA would also understand that there is no "deep leaning" without a deep neural network; the term "deep" describes the neural network.

45. DM's argument that a "deep learning device" does not use a neural network is incorrect in my opinion and inconsistent with claims, specification and file histories of the AI Patents. It is also inconsistent with the understanding of a POSA at the time of the alleged invention of the AI Patents as well as the extrinsic evidence.

2. A "Deep Learning Device" Classifies Data

46. In my opinion, a POSA at the time of the alleged invention would have agreed that a "deep learning device" means "a device that employs a deep neural network ***to classify data after being trained on an input dataset.***" This construction is supported by the claims, specification, a knowledge of a POSA and extrinsic evidence.

47. Grin's proposed construction is consistent with the claim language. A POSA would understand that a deep learning device employs a deep neural network "to classify data after being trained on an input dataset" and that this is evident from the AI Patent claims, which recite that upon being trained on a dataset, the "deep learning device" analyzes an image to make certain determinations. For example, in claim 1 of the '409 patent, the deep learning device determines "a value for an image attribute." '409 patent at 32:19-21. In claim 1 of the '983 patent, the deep learning device determines "the presence of a tooth at a position" on the image and "the attribute value of said tooth." '983 patent at 32:30-33; 32:42-51. A POSA would

understand from both claims, that the deep learning device must classify the data (i.e., the image) or parts of the data submitted to it in order to make these determinations.

48. The patent specification also shows this. It states:

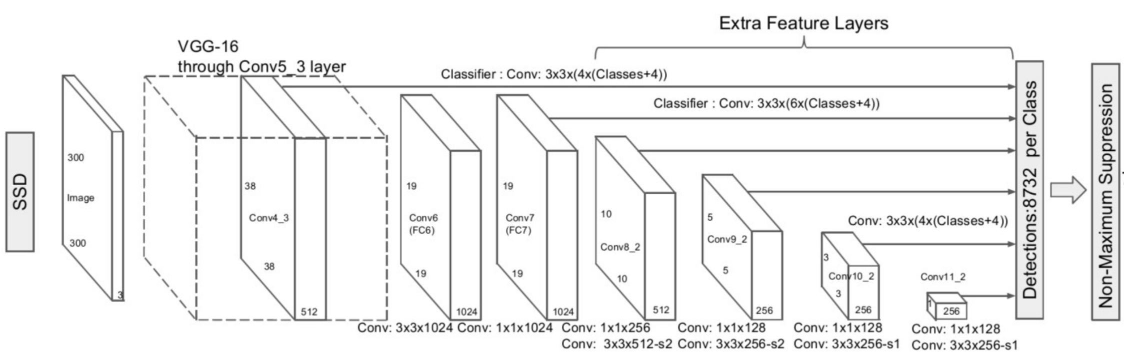
> A "neural network" or "artificial neural network" is a set of algorithms well known to a person skilled in the art.
>
> The neural network may in particular be chosen from:
>
> > [First Set of Examples] the networks specializing in the ***classification of images***, called "CNN" ("convolutional neural network"), for example
> > AlexNet (2012)
> > ZF Net (2013)
> > VGG Net (2014)
> > GoogleNet (2015)
> > Microsoft ResNet (2015)
> > Caffe: BAIR Reference CaffeNet, BAIR AlexNet
> > Torch: VGG_CNN_S, VGG_CNN_M, VGG_CNN_M_2048, VGG_CNN_M_10 24, VGG_CNN_M_128, VGG_CNN_F, VGG ILSVRC-2014 16-layer, VGG ILSVRC-2014 19-layer, Network-in-Network (Imagenet & CIFAR-10)
> > Google: Inception (V3, V4).
> >
> > [Second Set of Examples] The networks specializing in the ***location and detection of objects*** in an image, the object detection network, for example:
> > R-CNN (2013)
> > SSD (Single Shot MultiBox Detector: Object Detection network), Faster R-CNN (Faster Region-based Convolutional Network method: Object Detection network)
> > Faster R-CNN (2015)
> > SSD (2015).

'983 patent at 16:16-45. A POSA would understand that all of the networks listed as examples perform classification.

49. A POSA would understand that the first set of examples provided are convolution neural networks (or CNNs), which the patent explains specialize in the classification of images.

50. A POSA would also understand that the second set of examples—SSDs and R-CNN's—which are networks "specializing in the location and detection of objects in an image," are also examples of networks that perform classification. A POSA would understand that the

"R-CNN" and "Faster R-CNNs" perform classification because they employ, as their names indicate, CNNs. As for the other two examples—the SSDs—a POSA would also understand that SSDs use CNNs to perform classification. For example, the following image is from a 2016 paper titled "SSD: Single Shot Multibox Detector" that explains "[t]he SSD approach is based on a feed-forward convolution network … for the presence of object class instances." Ex. 7 (2016 Liu et al., *SSD: Single Shot MultiBox Detector* (Dec. 29, 2016)) at 1, 3. The image shows that the SSD has convolution layers labeled "Classifier: Conv" and the paper explains that "[t]he early network layers are based on a standard architecture used for high quality image ***classification***." *Id.* at 3.



Id. at 4. A POSA would understand from this that SSDs employ CCNs and perform classification.

51. A POSA would understand that classification of data is at the core of deep learning and the object detection and object location functions of a deep learning device. In order to recognize patterns, something the parties' constructions agree that neural networks do, neural networks perform classification. For example, to determine whether some part of an image is a tooth, a neural network must classify the data from that portion of the image as either "a tooth" or "not a tooth." This is similar to how the human brain—the inspiration for neural networks—recognizes patterns. For example, a toddler can recognize a teddy bear because her brain has been trained to recognize the collective features of that particular toy as a teddy bear. So when

she sees one, her brain classifies it as a teddy bear and not something else. The deep learning device claimed by the AI Patents similarly uses a neural network (the brain of the device) that is trained on a set of data (similar to the toddler's brain being trained by repeated exposures to teddy bears) such that when it is presented with an image of a tooth, it classifies that image as a tooth (and not something else) and determines that the image contains a tooth.

52. DM's argument that a "deep learning device" does not classify data is incorrect in my opinion and inconsistent with claims, specification and file histories. It is also inconsistent with the understanding of a POSA at the time of the alleged invention of the AI Patents as well as the extrinsic evidence.

B. Neural Network

Term	**Dental Monitoring's Construction**	**Get-Grin's Construction**
Neural network '983 Patent claims 1 and 12 '409 Patent claim 15	Plain and ordinary meaning ("One or more AI algorithms that employ layers of nodes, with weighted connections between the layers, that perform pattern recognition.")	A set of AI algorithms that employ layers of nodes, with weighted connections between the layers, and are used to perform pattern recognition and classification

53. In my opinion, a POSA at the time of the alleged invention for the AI Patents would have understood the term "neural network" to mean "a set of AI algorithms that employ layers of nodes, with weighted connections between the layers, and are used to perform pattern recognition and classification." This construction is supported by the claims, specification, a knowledge of a POSA as well as the extrinsic evidence. I incorporate by reference the discussion above from Section VII.A.2 of my declaration as if set fully forth herein.

54. Grin's proposed construction is consistent with the claim language. A POSA would understand that the AI Patent claims show that neural networks perform classification.

55. As I discussed for the previous term, "deep learning device", a POSA would understand that the AI Patents' claims and specification read together show that a neural network performs classification. For example, the specification states "[a] 'neural network' or 'artificial neural network' is a set of algorithms well known to a person skilled in the art" and provides a series of example algorithms that all perform classification. '983 patent at 16:16-45. A POSA would understand that this classification by the neural network is what enables the claimed "deep learning device" to analyze an image and make certain determinations about attribute values and tooth locations, as recited by the claims.

56. In addition, the References Cited on the face of the AI patents show that a POSA would have understood a neural network— "a set of algorithms well known to a person skilled in the art"—to perform classification. *See, e.g.*, '983 patent at 16:15-16; '409 patent at 16:15-16. For example, in a May 2017 cited reference titled "***Classification*** of Quantitative Light-Induced Fluorescence Images ***Using Convolutional Neural Network***" by Sultan Imangaliyev et al., the abstract explains "the ***deep neural network outperforms other state of the art shallow classification models*** in predicting labels derived from three different dental plaque assessment scores." Ex. 8 (S. Imangalivev et al., *Classification of Quantitative Light Induced Fluorescence Images Using Convolutional Neural Network* (May 25, 2017)) at DENTAL647_00017312. In another cited reference from 2012 titled "Teeth/Palate and Interdental Segmentation Using Artificial Neural Networks," by Kelwin Fernandez et al., the authors "combine[d] Artificial Neural Networks and other image processing techniques to achieve teeth/palate segmentation and interdental segmentation in palatal view photographs of the upper jaw." Ex. 9 (K. Fernandez & C. Chang, *Teeth/Palate and Interdental Segmentation Using Artificial Neural Networks* (2012)) at DENTAL647_00016659. The paper explains that "[t]he combination of input image

formats improved the ***classification rates of the Neural Networks***" and "[w]hen skin pixels are classified, some of them have information indistinguishable from teeth, therefore ***the neural network classifies*** them as positive examples." *Id* at DENTAL647_00016664 – 1665.

57. I disagree with DM's argument for excluding classification from the construction of "neural networks." I understand DM relies on a statement from the specification that "[t]he analysis image may advantageously be classified automatically. It may also be used immediately by a computer program." DM Brief at 7 (quoting '983 patent at 1:63-65). In my opinion, DM fails to take into account the context of this statement. The specification here is not discussing whether the neural network does or does not classify. In the preceding statements in column 1, the patent explains that a deep learning device can be used to perform analysis-by-tooth to determine the presence of a tooth at a particular location and the type of tooth. *Id.* at 1:50-58. The next statement (i.e., the one DM relies on), explains that the image itself also may be automatically classified. A POSA would understand that this is a reference to a global classification of the image to determine the attribute for the image as a whole in contrast to the previously described analysis-by-tooth.

58. In my opinion, Grin's construction, which is consistent with the claims, intrinsic record, and the ordinary meaning of "neural network" as well as the knowledge of a POSA and the intrinsic record, is correct.

59. A POSA would understand that classification of data is a function of a neural network and is necessary for the object detection and object location functions of a deep learning device. As I discussed above, in order to recognize patterns, something the parties agree neural networks do, neural networks perform classification.

60. DM's argument that a "neural network" does not classify data is incorrect in my opinion and inconsistent with claims, specification and file histories. DM's construction omits an essential function of a neural network as it is described in the AI Patents—classification. It is also inconsistent with the understanding of a POSA at the time of the alleged invention of the AI Patents as well as the extrinsic evidence.

C. Creation of a Learning Base

Term	Dental Monitoring's Construction	Get-Grin's Construction
Creation of a learning base '983 Patent claims 1 and 12 '409 Patent claims 3 and 7	Plain and ordinary meaning ("creation of a collection of images and corresponding attribute values for those images")	Acquiring images and identifying and storing attribute values for acquired images to create a database to be used in the training of the Deep Learning Device

61. In my opinion, a POSA at the time of the alleged invention for the AI Patents would have understood the term "creation of a learning base" to mean "acquiring images and identifying and storing attribute values for acquired images to create a database to be used in the training of the Deep Learning Device." This construction is supported by the claims, specification, a knowledge of a POSA as well as the extrinsic evidence.

62. Grin's proposed construction is consistent with the claim language. The claims recite that the contents of the learning base are images and their attribute values. *See, e.g.*, '983 at 32:34-39 (claim 1) ("creation of a learning base comprising more than ***1000 images of dental arches***, or 'historical images', each historical image comprising one or more zones each representing a tooth, or 'historical tooth zones', to each of which, for at least one tooth attribute, a ***tooth attribute value is assigned***."); *see also id.*, 34:29-32 (claim 12); *see also* '409 patent,

claims 3, 7. A POSA would understand from this that the learning base includes images and attribute values.

63. A POSA would also understand that the "***creation of*** a learning base" means "***acquiring images and identifying and storing attribute values for acquired images*** to create a database to be used in the training of the Deep Learning Device." A POSA would understand that the claims support Grin's construction of "creation" to require "acquiring images." The claims recite that the learning base comprises more than "1000 images of dental arches, or 'historical images.'" *See, e.g.*, '983 patent at 32:34-35 (claim 1). A POSA would understand that in order to create a learning base that includes images, the images first must be acquired. In my opinion, a POSA would understand the word "acquiring" in Grin's construction to mean collecting.

64. It is my opinion that the acquisition of images for a learning base is a requirement for the creation of a learning base. I understand that methods to acquire images for a learning base were well understood by a POSA at the time of the alleged invention of the AI Patents. Various techniques were used to acquire training images, for example by capturing new images using a camera or by selecting images from a set of existing (i.e., already captured and stored) images or by scraping the internet or using search engine APIs. *See, e.g.*, Ex. 13 (*Deep Convolutional Neural Network Features and the Original Image* (Nov. 6, 2016)).

65. A POSA would also understand that the claims support construing "creation" to require "identifying and storing attribute values for acquired images." The claims recites that the learning base includes attribute values. '983 patent at 32:34-39 (claim 1). A POSA would understand that before attribute values can be stored in a learning base, those attribute values must be identified.

66. A POSA would also understand from the context of the surrounding claim language that the "learning base" is to be "used in the training of the deep learning device" as stated in Grin's construction. The claims recite that the "learning base" is used in the training of the Deep Learning Device. *See, e.g.*, '983 patent at 32:40-41 (claim 1) ("B) training of at least one deep learning device, ***by means of the learning base***."). Grin's construction points out the connection between the two steps and puts the creation of the learning base into context. A POSA also would understand that the step of "training of at least one deep learning device, by means of the learning base" recited in the claims is a separate limitation from the step of the creation of a learning base to train the deep learning device. A POSA also would understand that the step of "training of at least one deep learning device, by means of the learning base" recited in the claims indicates that the step of training is performed. '983 patent, 32:40-41 ("B) training of at least one deep learning device, by means of the learning base.").

67. In my opinion, Grin's construction, which gives meaning to the entire limitation and is based on the claims and intrinsic evidence, is correct. Grin's construction gives meaning to the entire term. DM's construction, on the other hand, reuses the word "creation" without explaining what "creation" means.

VIII. CONCLUSION

68. I declare that all statements made herein of my knowledge are true, and that all statements made on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

This declaration was executed on November 22, 2023 in Tempe, Arizona.

By:________________________________

Lina Karam

APPENDIX A

LINA J. KARAM

Fellow of the IEEE
Emerita Professor, School of ECEE, Arizona State University, USA
President and Expert Consultant, PICARIS LLC
Chief Technical Advisor, Sustainable Engineering Group and AIAEC
Email: ljkaram@gmail.com, karam@asu.edu
Phone: +1 480 703 6053 (US)
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R&D Topics and Publications Highlights

Signal, Image, and Video Processing, Compression, and Transmission; Computer Vision; Artificial Intelligence, Machine Learning; Deep Learning; Autonomous Vehicles; Perceptual-based Processing; Visual Attention Models; Automated Quality Assessment; Multidimensional Signal Processing; Biomedical Signal Processing; Joint Source-Channel Coding; Digital Filter Design. **Supervised to completion as main advisor 47 graduate students (24 PhD and 23 MS Thesis students).**

Industry Collaborations and Technology Transfer

R&D collaborations on signal processing, computer vision, machine learning, quality assessment/QoE, imaging, image/video processing, compression, and communication projects with various industries including Intel, Qualcomm, Google, NTT, Motorola, Freescale, General Dynamics, NASA, BNI, and TGEN; elected to IEEE Fellow for contributions in perceptual-based visual processing, image and video communications (including video compression and transmission) and digital filtering; image and video processing and compression development at AT&T Bell Labs (Murray Hill); work on digital filtering widely adopted for the development of improved applications and products in various sectors including but not limited to telecommunications, transmission, health, signal processing, and geophysical applications, and part of which has been integrated in the widely used MATLAB Signal Processing Toolbox (as the cfirpm function); multi-dimensional data processing and visualization at Schlumberger; very low bit-rate scalable video codecs development and productization in collaboration with General Dynamics; satellite-based video communication development and productization in collaboration with General Dynamics; image and video processing, computer vision, machine learning, and autonomous driving technologies development with Intel; technical advisor as part of AVTC ECOCAR Mobility Challenge; co-founder of biotech startup with product licensed to healthcare industries; inventor on patented image/video compression and communication, computer vision, and machine learning technologies.

Highlights

Led various teams within and across disciplines including but not limited to R&D, project management, productization, administrative, technical, and editorial teams.
Inventor on 8 issued US patents and on one published US Patent Application.
Expert delegate of the ISO/IEC JTC1/SC29 Committee (Coding of audio, picture, multimedia and hypermedia information) and participating in JPEG/MPEG standardization activities including machine learning based visual compression.
Expert consulting in IP/Patents, Signal Processing, Image/Video Coding, Image/Video Processing, Image/Video Compression and Communication, Computer Vision, Machine

Learning. *Check out open access AI/Machine Learning Hands-On Book at:* https://deeplearningtextbook.org/
Emerita Professor, School of ECEE, Arizona State University (2020-Present)
Director, Image, Video & Usability (IVU) R&D Laboratory at ASU (1995-Present)
Editor-In-Chief, IEEE Journal on Selected Topics in Signal Processing (2019-2021)
National Academy of Inventors, ASU Chapter (2019-Present)
Featured in Stanford Study among the top 2% of World Scientists in AI and Image Processing
Featured in 8th and 9th editions of Research.com (2022 and 2023) among World Top Computer Science Scientists
Dean, School of Engineering, Lebanese American University (2020-2022)
Director, Real-time Embedded Signal Processing (RESP) Laboratory at ASU (2000-2019)
Computer Engineering Program Chair, ASU Fulton Schools of Engineering (2016-2017)
Director of Industry Engagement, ASU Fulton Schools of Engineering (2018-2019)
President, PICARIS, LLC, a consulting company (2007-present)

Established the World's First Visual Innovation Award in 2016:
https://fullcircle.asu.edu/faculty/visual-tech-visionaries-honored-innovation-awards/
https://www.youtube.com/watch?v=pEZ2mT5sASw

Established the World's First Multimedia Star Innovator Award in 2019.

Established in 2018 an ASU-Silicon Valley Fellowship/Internship Program for Graduate Students (Computer Engineering, Electrical Engineering, Computer Science, Industrial Engineering) with TCL Research America as founding partner.

Established and led in 2018 a University-wide Intel-ASU Collaborative Initiative on Automated Mobility/Autonomous Cars with Intel, ADOT, DPS and GPEC as partners, which culminated in the establishment of the Governor's Institute on Automated Mobility (IAM) at the state level.

Established transdisciplinary Intel-ASU Autonomous Vehicle initiative (2017-2018) and lead PI on grant (funded in 2018):
https://transportation.asu.edu/projects/intel-asu-autonomous-vehicle-initiative/

ADAS lead advisor as part of the DoE/GM-sponsored Advanced Vehicular Technologies (AVTC) EcoCAR3 competition (2017-2018):
https://avtcseries.org/about-avtc/past-competitions/ecocar-3/

Interview with KJZZ 91.5 radio (NPR radio station in AZ) - Preliminary Report: Self-Driving Uber Car Didn't Alert Driver Of Collision Possibility (May 24, 2018):
https://kjzz.org/content/642626/preliminary-report-self-driving-uber-car-didnt-alert-driver-collision-possibility

Podcast-Driverless Cars (August 31, 2018): https://www.hh-wm.com/podcast/driverless-cars/

Interview with FOX 10 News - Cities and Driverless Cars (October 30, 2018):
http://www.fox10phoenix.com/news/arizona-news/cities-looking-at-how-self-driving-cars-can-change-their-communities

Interview with Phoenix Business Journal - Waymo and Self-Driving Truck Testing (May 29, 2019):
https://www.bizjournals.com/phoenix/news/2019/05/29/waymo-to-resume-self-driving-truck-testing-in.html

Judge on Vision Tank 2019 Start-Up Competition, Embedded Vision Summit, Santa Clara, CA, USA (May 22, 2019):
https://www.youtube.com/watch?v=X-bed7c04lY&feature=youtu.be&t=3

Interview with Associated Press - Verification stamps weren't pre-printed on Arizona ballot envelopes (September 29, 2021):
https://apnews.com/article/fact-checking-205460259311

Established in 2020-2022 the award-winning VIP+ program across various schools and disciplines, adapting the Georgia Tech's Vertically Integrated Projects (VIP) model by intergrating an explicit entrepreneurial component into VIP, and served as VIP+ program director and lead LAU PI on grant funded by the US Department of State (US MEPI TLP grant); the established VIP+ program was granted three awards in 2022 by the International VIP Consortium consisting of 44 institutions in 13 countries (out of which 25 institutions are in the US):
https://news.lau.edu.lb/2022/laus-vertically-integrated-project-wins-major-international-consortium-awards.php
https://www.vip-consortium.org/node/1422
https://news.lau.edu.lb/2021/new-mepi-grant-to-boost-employability.php
https://mepitl.lau.edu.lb/news/the_lau_school_of_engineering_or.php
Video with students' testimonials: https://youtu.be/W0y1WNnd9ko

Established in 2021 a partnership between the United Nations Development Program (UNDP)'s Energy Innovation Hub and LAU School of Engineering and secured UNDP grant funding:
https://eihub-lb.com/

Led an initiative with a consortium of industry partners to help advance the Renewable Energy/Solar Industry Sector in Lebanon and served as lead PI on USD multi-million proposal to USAID Trade and Investment Fund (USAID-TIF) to establish a photovoltaic (PV) pilot scale module manufacturing facility, a certified PV testing facility and a training facility to assist the local solar energy companies to build customizable high-quality PV panels. The submitted proposal was highly scored and has been selected to move to the co-creation stage with industry partners.
https://www.linkedin.com/feed/update/urn:li:activity:6894991934830501889/
https://news.lau.edu.lb/2022/toward-solar-panels-made-in-lebanon.php
https://news.lau.edu.lb/2022/harnessing-solar-energy-in-lebanon-with-the-support-of-usaid.php

Established in 2021 the First ENPMED (Engineering PreMed) program incorporating a Premed track in all engineering majors at the Lebanese American Univesity (LAU):
https://news.lau.edu.lb/2021/medicine-by-way-of-engineering-new-premed-track-at-lau.php

Established in 2021 iLEAP (industry-focused Lebanese Education & Academia Partnership) between LAU and LebNET (https://lebnet.us/), a non-profit US organization focused on education and mentoring, and comprising a network of technology experts, Fortune 500 managers and executives, venture capitalists and investors, startup founders and entrepreneurs, academics, consultants and small business owner in North America:
https://lebnet.us/LAU-iLEAP
https://news.lau.edu.lb/2021/lebnet-lau-initiative-adds-leverage-for-engineering-students.php

Developed and submitted to LAU's Board of Trustees in 2021 a proposal and business plan to establish the *LAU Industrial Hub*. The proposal was approved by LAU's Board of Trustees.

Interview with Al Nahar Newspaper – Engineering Premed (ENPMED), Medicine and Medical Technologies through Engineering (December 14, 2021): https://www.annahar.com/arabic/section/77-%D9%85%D8%AC%D8%AA%D9%85%D8%B9/13122021062414414

SHORT BIO

Lina Karam is currently an Emerita Professor at Arizona State University. She is an Expert Consultant and President of PICARIS, LLC. She is also Chief Technical Advisor at Sustainable Engineering Group and AIAEC. Prior to becoming Emerita Professor, she was a tenured Full Professor, Computer Engineering Program Chair, Computer Engineering Director for Industry Engagement at Arizona State University. From 2020 to 2022, Dr. Karam served as Dean of the School of Engineering at the Lebanese American University. Dr. Karam is an IEEE Fellow, the highest grade level in IEEE which is conferred each year to no more than one-tenth of 1% of all IEEE voting members, for her contributions in the image and video processing, visual media coding and transmission, and digital filtering areas. Dr. Karam has been featured in Research.com among World Top Computer Science Scientists and in Stanford Study among the top 2% of World Scientists in AI and Image Processing. Dr. Karam is a recipient of the National Science Foundation CAREER Award, NASA Technical Innovation Award, the Intel Outstanding Researcher Award, the IEEE SPS Best Journal Paper Award, the IEEE Phoenix Section Outstanding Faculty Award, and the IEEE Region 6 Award. She served as Editor-in-Chief of the high-impact IEEE Journal on Selected Topics in Signal Processing (IEEE JSTSP) from 2019 to 2021. At ASU, Dr. Karam helped in establishing two transdisciplinary programs, the Computer Engineering Program (across Computer Science and Electrical Engineering) and the Robotics & Autonomous Systems (RAS) Program (across four schools). Dr. Karam served on the IEEE Signal Processing Society (SPS) Board of Governors, IEEE SPS Conference Board, IEEE SPS Publications Board, IEEE SPS Awards Board, IEEE Circuits and Systems (CAS) Fellow Evaluation Committee, IEEE PSPB Strategic Planning Committee, IEEE TechRxiv Advisory Board (as Chair), IEEE SPS IVMSP and MMSP Technical Committees, IEEE CAS DSP Technical Committee, and various journal editorial boards. She served as the General Chair of IEEE ICIP 2016, General Co-Chair of IEEE ICME 2019, Technical Program Chair of IEEE ICIP 2009, General Chair of IEEE DSP/SPE 2011 Workshops. She cofounded the International Conference on Quality of Multimedia Experience (QoMEX). In addition to serving as the EiC of IEEE JSTSP, Dr. Karam served as the Lead Guest Editor, IEEE Signal Processing Magazine, Special Issue on Autonomous Driving. She is also serving on the IEEE Access Journal Senior Editorial Board, IEEE TechRxiv Editorial Board, Foundation and Trends in Signal Processing Journal Editorial Board, IEEE EAB Faculty Resources Committee and IEEE TAB/PSPB Products and Services Committee. She is an inventor with 8 issued US patents in the fields of image/video processing, coding, and transmission, computer vision, and AI/Machine Learning. She served as expert delegate of the ISO/IEC JTC1/SC29 Committee (Coding of audio, picture, multimedia and hypermedia information) and participated in JPEG/MPEG standardization activities including integrating AI within upcoming standards.

EDUCATION

Georgia Institute of Technology

Ph.D., Electrical Engineering, 1995

M.S., Electrical Engineering, 1992

American University of Beirut

B. E., Computer and Communications Engineering, 1989.

EMPLOYMENT/POSITIONS

Chief Technical Advisor, Sustainable Engineering Group and AIAEC (August 2023 – present)

President and Expert Consultant, PICARIS LLC, a technology consulting company (2007-present)

Emerita Professor and Director of R&D IVU Lab, School of Electrical, Computer & Energy Engineering, Arizona State University, USA (2020-present)

Professor and Dean, School of Engineering, Lebanese American University (2020-2022)

Computer Engineering Graduate Program Chair and Director of Industry Engagement (2016-2018), Arizona State University, Tempe, AZ

Professor and Director of R&D IVU Lab (May 2010 – Dec 2019), School of Electrical, Computer and Energy Engineering, Arizona State University, Tempe, AZ.

Associate Professor and Director of R&D IVU Lab (August 2001 – May 2010), School of Electrical, Computer, and Energy Engineering (formerly known as Department of Electrical Engineering), Arizona State University, Tempe, AZ.

Visiting Associate Professor (August 2005 – December 2005), Department of Electrical and Computer Engineering, The University of Texas at Austin, Austin, TX.

Assistant Professor and Director of R&D IVU Lab (August 1995 – August 2001), Department of Electrical Engineering, Arizona State University, Tempe, AZ.

Intern (1994), AT&T Bell Laboratories, Murray Hill, NJ.

Research Assistant (September 1992 – June 1995), School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA.

Research Assistant (June 1991 – September 1992), Graphics, Visualization, and Usabilty (GVU) Center, Georgia Institute of Technology, Atlanta, GA.

Intern (1992), Schlumberger, Austin, TX

Research Assistant (February 1990 - June 1991), Scientific Visualization Group, Georgia Institute of Technology, Atlanta, GA.

Intern (1988), Computing Department, Imperial College, London, UK.

INVITED PRESENTATIONS, SHORT COURSES, AND SELECT PANELS

1. *Invited Lecturer*, "Deep Learning for Quality Robust Visual Recognition," DeepLearn 2022, Guimaraes, Portugal, https://irdta.eu/deeplearn2022sp/
2. *Featured guest,* "Artificial Intelligence in Lebanon: Reality and Need," 1st Webinar and Panel Discussion on Artificial Intelligence being organized by the Order of Engineers and Architects in Lebanon (in-person and live streamed over social media), 11 February 2022. https://soe.lau.edu.lb/school/news/2022/webinar-and-panel-discussion-on-.php https://www.facebook.com/oeabeirut/videos/470212477889219/
3. *Panelist,* "Diversity Faculty Sharing Experiences," IEEE PROGRESS Workshop, USA, June 2021, October 2021, and June 2020.

4. *Keynote Speaker,* "Resilient Machine Learning for Automated Mobility," Communications of the ACM (ACM) Arabia Workshop, August 2020.
5. *Plenary/Keynote Speaker,* "Towards Resilient Deep Learning," IEEE International Conference on Image Processing, October 2020.
6. *Session Moderator,* Embedded Vision Summit, Silicon Valley, USA, May 2020.
7. *Judge/Panelist,* Vision Tank 2019 Start-Up Competition, Embedded Vision Summit, Santa Clara, CA, USA, May 2019.
8. *Invited Talk,* "Resilient Deep Learning through Feature Regeneration," Intel Corporation, Phoenix, AZ, April 2019. *Talk hosted by IEEE WIE Phoenix.*
9. *Panelist (the only engineer on panel among 6 panelists) with Waymo's CExO,* "Let's Talk Self-Driving: A Fireside Conversation with Waymo's Tekedra Mawakana," Arizona State University, Tempe, AZ, USA, April 2019.
10. *Invited Talk,* "Understanding Automated Driving Systems Technologies," Connected and Autonomous Vehicles 101 (CAV 101) Seminar and Roadshow; Education for Arizona Small Towns ans Satellite Cities; Tempe, AZ, USA, March 2019.
11. *Invited Talk and Panelist,* "Towards Safe, Efficient Automated Driving at Scale," American Bar Association (ABA) Smart Cities Conference, Tempe, AZ, USA, February 2019.
12. *Invited Talk,* "Generative Sensing: Reliable Recognition from Unreliable Sensor Data," Embedded Vision Summit, Santa Clara, CA, May 2018. ***Talk highly ranked by attendees.***
13. *Plenary Talk*, "Generative Sensing," International Conference on Computing, Networking, and Communications (ICNC), Maui, Hawaii, March 2018.
14. *Plenary Talk*, "Generative Sensing: Transforming Unreliable Sensor Data for Reliable Recognition," Twenty-Fourth National Conference on Communications (NCC) 2018, IIT Hyderabad, India, February 2018.
15. *Distinguished Speaker*, "A Closer Look at Visual Attention Models," College of Engineering, Penn State University, April 2017.
16. *Invited Tutorial Lecture*, "Introduction to Image and Video Compression," Visual Signal Analysis and Processing (VSAP) Workshop, Khalifa University, Abu Dhabi, United Arab Emirates, November 2015.
17. *Plenary Distingushed Lecture*, "Attentive Visual Processing – Towards User-Centric Visual Technologies," International Conference on Computing, Networking and Communications (ICNC), February 2014.
18. *Intel Webinar*, "Automated Defect Detection and Identification for Semiconductor Units Undergoing Assembly and Test," Intel Corporation, November 2011.
19. *Plenary Talk*, "Efficient Perceptual-Based Image and Video Processing," Tenth FEA Student Conference, American University of Beirut, Beirut, Lebanon, May 2011.
20. *Expert Panel Talk*, "Trends in 3D Video Processing," IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), May 2011.
21. *Invited Talk*, "Foundations and Trends of Visual Quality Assessment," American University of Beirut, Beirut, Lebanon, July 2010.
22. *Plenary Talk,* "Foundations and Trends of Visual Quality Assessment," 2nd International Workshop on Visual Information Processing (EUVIP), Paris, France, July 2010.
23. *Invited Talk*, "Adaptive Rate-Distortion Based Wyner-Ziv Video Coding," Multimedia, Mathematics and Machine Learning II, BIRS, Banff Centre, Banff, Canada, July 2009.

24. *Invited Talk*, “Wyner-Ziv Based Low-Complexity Distributed Video Encoding,” New Mexico State University, Las Cruces, NM, Nov. 2008.
25. *Invited Lecture*, "Real-World Applications for Freshman Engineering Education," NI Week, Austin, TX, Aug. 2008.
26. *Invited Lecture,* “From Conventional to Distributed Video Coding,” IEEE Lebanon Section and American University in Beirut, Beirut, Lebanon, July 2008.
27. *Invited Lecture*, “BLAST-DVC: BitpLAne SelecTive Distributed Video Coding,” Center for Research in Mathematics (CIMAT), Guanajuato, Mexico, May 2008.
28. *Short Course,* Lina J. Karam, “Image Compression: Foundations,” Qualcomm, San Diego, CA, May 2008. Invited One-Day Short Course.
29. *Short Course,* Lina J. Karam, “Basics of Image and Video Compression,” Qualcomm, San Diego, CA, 2007. Invited Two-Day Short Course.
30. *Guest Speaker,* “Functional MRI,” National Instruments, Austin, TX, 2007.
31. *Invited Talk*, “Selective Error Detection for Error-Resilient Image Coding and Transmission using Similarity Check Functions,” Ss Cyril and Methodius University, Skopje, Macedonia, 2006.
32. *Guest Speaker,* “Freshman Introduction to Engineering,” National Instruments, Austin, TX, 2005.
33. *Invited Speaker,* “Wavelet-Based Adaptive Image Denoising with Edge Preservation,” General Dynamics, Scottsdale, AZ, 2004.
34. *Invited Talk*, “Teaching Image Processing to High School Students,’’ IEEE Digital Signal Processing Workshop, Hunt, TX, 2000.
35. *Invited Talk,* “Error-Resilient Video Coding with Channel-Optimized Trellis-Coded Quantization,’’ IEEE Wireless Communications and Networking Conference, Chicago, IL, 2000.
36. *Invited Talk*, “Channel-Optimized Source Coding for the Transmission of Digital Imagery over Noisy Channels,” The American University of Beirut, Beirut, Lebanon, July 2000.
37. *Invited Talk*, “Robust Image Coding Using Perceptually-Tuned Channel-Optimized Trellis-Coded Quantization,’’ Midwest Symposium on Circuits and Systems, Las Cruces, NM, 1999.
38. *Guest Speaker*, “Image Coding based on Perceptual Criteria,” Motorola, Scottsdale, AZ, 1996.
39. *Distinguished Lecture*, “Color Video Coding at Very Low Bit Rates,” IEEE Signal Processing & Communications Chapter, Phoenix, AZ, 1995.

AWARDS AND RECOGNITION

- IEEE Fellow
- Editor-In-Chief, IEEE Journal on Selected Topics in Signal Processing (Jan 2019-Dec 2021)
- Invited Lecturer at DeepLearn 2022
- Invited Plenary/Keynote Speaker at the 2020 IEEE International Conference on Image Processing (IEEE ICIP)
- National Academy of Inventors, ASU Chapter (inducted in 2019)
- IEEE Region 6 "Outstanding IEEE member who promoted Women in Engineering" Award, 2018

- IEEE Phoenix Section Outstanding Contribution to Promoting Women in Engineering (WIE) Award, April 2018
- Certificate of Recognition, IEEE Signal Processing Society, September 2016
- IEEE Signal Processing Society's Best Paper Award (IEEE Transactions Journal Paper)
- IEEE Signal Processing Society's Board of Governors.
- QoMEX 2012 Best Paper Award, July 2012
- Intel Outstanding Researcher Award, March 2012
- Outstanding Faculty Award, IEEE Phoenix Section, February 2012
- American University of Beirut Distinguished Alumnus Award, 2011
- Certificate of Merit, IEEE Signal Processing Society, 2009
- Founding Member, US Representative, QUALINET, European Network on Quality of Experience in Multimedia Systems and Services (Founded in 2009), http://www.qualinet.eu/
- NASA Technical Innovation Award for work on visual coding, 2006
- Outstanding Technical Contributions Award, Digital Signal Processing, IEEE Phoenix Section, Jan. 2005.
- Senior Member of the Institute of Electrical and Electronics Engineers (IEEE), January 2003.
- Professional Leadership & Service Recognition from the IEEE Signal Processing and the IEEE Communications societies
- U.S. National Science Foundation CAREER Award for work on perceptual-based image/video coding
- Society of Women Engineers Outstanding Graduate Student Award at Georgia Tech

EDITORSHIP

- Editor-In-Chief, IEEE Journal on Selected Topics in Signal Processing (Jan 2019-Dec 2021).
- Lead Guest Editor, IEEE Signal Processing Magazine, Special Issues on Autonomous Driving (2019-2021)
- Senior Editorial Board, IEEE IoT Magazine (2021-present)
- Editorial Board, IEEE Access (2019-present)
- Chief Guest Editor for the Proceedings of the IEEE, Special Issue on Perceptual-Based Media Processing (2011-2013)
- Senior Editorial Board of the IEEE Signal Processing Magazine (2014-2019).
- Editorial Board of the IEEE Journal on Selected Topics in Signal Processing (2014-2017).
- Editorial Board, Foundation and Trends in Signal Processing (2006-present).
- Guest Editor for EURASIP Journal on Video Quality Metrics (2012-2013).
- Guest Editor for the IEEE Signal Processing Magazine, Special Issue on Multimedia Quality Assessment (2010-2011).
- Guest Editor for the EURASIP Journal on Image and Video Processing, Special Issue on Quality of Multimedia Experience (2009-2011).
- Lead Editor for the IEEE Journal on Selected Topics in Signal Processing, Special Issue on Visual Quality Assessment (2007-2009)
- Editorial Board of the IEEE Transactions on Image Processing (1999-2003 & 2006-2010)
- Editorial Board of the IEEE Signal Processing Letters (2004-2006)

CONFERENCE ACTIVITIES

- Publicity Co-Chair, International Conference on Quality of Multimedia Experience (QoMEX), 2022.
- Awards Co-Chair, IEEE International Conference on Multimedia Information Processing and Retrieval (IEEE MIPR), 2022.
- Awards Co-Chair, IEEE International Conference on Image Processing, 2021.
- General Co-Chair of the IEEE International Conference of Multimedia and Expo (ICME), Shanghai, China, July 2019.
- General Chair of the 23rd IEEE International Conference on Image Processing (ICIP), Phoenix, AZ, September 2016.
- Initiator of the World's First Visual Innovation Award presented for the first time at IEEE ICIP 2016, and of the World's First Multimedia Star Innovator Award presented for the first time at IEEE ICME 2019.
- Initiator of the IEEE Xplore Open Paper Preview, which makes papers freely available open access prior to held conference and which results in higher impact for papers.
- Member of the organizing committee of the QoMEX 2016 conference (Lisbon, Portugal).
- Area Chair, 2015 IEEE International Conference on Image Processing (ICIP) and 2015 IEEE International Conference on Circuits and Systems (IEEE CAS).
- General Chair (together with Jorge Caviedes) of the 2012 International Workshop on Video Processing and Quality Metrics for Consumer Electronics (VPQM), January 2012.
- General Chair (together with Ron Schafer) of the 2011 IEEE Digital Signal Processing and IEEE Signal Processing Education Workshops, Sedona, AZ, January 2011.
- Technical Program Chair (together with Thrasos Pappas) of the 2009 IEEE International Conference on Image Processing.
- Co-Founder (together with Touradj Ebrahimi, *EPFL*, Kahled El-Maleh and Gokce Dane, *Qualcomm*), of the International Workshop/Conference on Quality of Multimedia Experience (QoMEX). http://www.qomex.org
- Co-Founder (together with Jorge Caviedes, *Intel*, and Sanjit Mitra, *UCSB and USC*) of the International Workshop on Video Quality for Consumer Electronics (VPQM). http://www.vpqm.org
- Technical Program Chair (together with Gokce Dane) of the First International Workshop on Quality of Multimedia Experience (QoMEX 2009).
- Technical Program Chair of the First International Workshop on Video Quality for Consumer Electronics (VPQM 2005).
- Served on the Organizing Committees and on the Technical Committees of several other international conferences.

SCIENTIFIC AND PROFESSIONAL SOCIETY MEMBERSHIPS

- IEEE Fellow (2013-present).
- IEEE Technical Activities Board (TAB)/Publication Services and Products Board (PSPB) Products and Services Committee (2023-present)

- IEEE Educational Activities Board (EAB) Faculty Resources Committee (2023-present)
- IEEE Access Journal Senior Editorial Board (2019-present)
- IEEE TechRxiv Editorial Advisory Board (2022-present)
- IEEE TechRxiv Advisory Board (2019-2021) and Ad-Hoc Committee Chair (2021)
- IEEE Signal Processing Society's Conference Board (2003-2005 & 2017-2018 & 2021)
- IEEE Signal Processing Society's Publications Board (2019-2021)
- IEEE Signal Processing Society's Awards Board (2019-2020)
- IEEE Journal of Selected Topics in Signal Processing Senior Editor Board (2019-2021)
- IEEE Circuits and Systems Society's Fellow Evaluation Committee (2018 – 2019)
- IEEE Signal Processing Society's Board of Governors (2016 - 2018)
- IEEE Signal Processing Society's TC Review Committee (2016 - 2017)
- IEEE Signal Processing Society's Image, Video, and Multidimensional Signal Processing (IVMSP) Technical Committee (2005-2011 & 2014-2020)
- IEEE Circuits and Systems (CAS) Society's DSP Technical Committee (1996-present)
- Member of the IEEE Publication Services and Products Board (PSPB) Strategic Planning Committee (2014-2016).
- Member of the Award Board and Initiator of the World's First Visual Innovation Award presented for the first time at IEEE ICIP 2016.
- Member of the IEEE Signal Processing Society's Multimedia Technical Committee (2011-2014).
- Member of the IEEE Signal Processing Society's Appointments and Nominations Committee (2011-2014).
- Elected Member and Vice Chair of the IEEE Signal Processing Society's Education Technical Committee (2010-2012).
- Member of the IEEE Signal Processing Society's Technical Directions Board (2008-2009), and Chair of its Diversity Committee (2009).
- Member of the IEEE Signal Processing Society, IEEE Circuits and Systems Society, and IEEE Communications Society.
- Member of the Institute of Electrical and Electronics Engineers (IEEE).

JOURNALS / PROPOSALS / PATENTS / PROGRAMS REVIEWER

- Reviewer for IEEE, Elsevier, and ACM journals
- Reviewer on NSF (USA) panels
- Reviewer for NSF (USA) grant proposals including SBIR proposals
- Reviewer for NSERC (Canada) grant proposals
- Reviewed grant proposals for national and international universities
- Reviewed DoD (USA) proposals
- Reviewer and consultant on patent validation and litigation
- Leader of Assessment of Engineering and Computer Science University Programs at the international level.

SELECT UNIVERSITY SERVICE

- Dean of Engineering, LAU (2020-2022)
- Computer Engineering Director, Industry Engagement, ASU (2018-2019)

- Initiated and led transdisciplinary initiatives on automated mobility and self-driving cars across four ASU campuses (Tempe, Downtown, Polytechnic, Washington DC) and across various schools and established academia-university-government partnerships, ASU (2017-2019)
- ADAS lead faculty advisor as part of the DoE/GM-sponsored Advanced Vehicular Technologies (AVTC) ECOCAR (EcoCAR3) Mobility Challenge, ASU (2017-2018)
- Established an ASU-Silicon Valley partnership and fellowship with TCL Research America as founding member (2018)
- Computer Engineering Program Chair, ASU (2016-2017)
- Helped in establishing two new transdisciplinary degree-granting graduate programs and served on their Graduate Program Committees (GPC) at ASU:
    - Computer Engineering (CEN): transdisciplinary program between 2 schools
    - Robotics and Autonomous Systems (RAS): transdisciplinary program between 4 schools
- University Promotion & Tenure Committee, ASU
- Engineering Dean's Faculty Advisory Council (DFAC), ASU

PATENTS

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1. Tinku Acharya, Lina J. Karam, and **Francescomaria Marino**, "The Compression of Color Images Based on a 2-Dimensional Discrete Wavelet Transform Yielding a Perceptually Lossless Image," US Patent 6,154,493. Filed 1998 by Intel. **Issued 2000.**
2. Tinku Acharya, Lina J. Karam, and **Francescomaria Marino**, "Real-time Algorithms and Architectures for Coding Images Compressed by DWT-Based Techniques," US Patent 6,124,811. Filed 1998 by Intel. **Issued 2000.**
3. Glen P. Abousleman, **Tuyet-Trang Lam**, and Lina J. Karam, "Communication System and Method for Multi-Rate, Channel-Optimized Trellis-Coded Quantization," US Patent 6,717,990. Filed 2000 by Motorola. **Issued 2004.**
4. **Katherine S. Tyldesley**, Glen P. Abousleman, and Lina J. Karam, "System and Method for Transmission of Video Signals using Multiple Channels," US Patent 7551671 B2. Filed 2003 by General Dynamics. **Issued June 2009.**
5. Glen P. Abousleman, **Wei-Jung Chien** and Lina J. Karam, "Method and Apparatus for Network-Adaptive Video Coding," US Patent Application Publication No. 2008/0259796 A1. **Published October 2008**.
6. Lina J. Karam and **Asaad F. Said**, "Automatic Cell Migration and Proliferation Analysis," United States Patent 9,082,164. **Issued July 14, 2015.**
7. Lina J. Karam and **Samuel Dodge**, "Systems, Methods, and Media for Identifying Object Characteristics Based on Fixation Points," United States Patent 9,501,710 B2. **Issued November 22, 2016.**
8. Lina J. Karam and **Jinjin Li**, "Stereo Vision Measurement System and Method," United States Patent 9,704,232 B2. Full Patent Filed March 18, 2015. **Issued July 11, 2017. Technology Licensed by Intel through Arizona Technology Enterprises (AzTE).**

9. Lina J. Karam and **Tejas Borkar**, "Systems and Methods for Feature Corrections and Regeneration for Robust Sensing, Computer Vision, and Classification," United States Patent US11,0304,85. **Issued June 2021**.

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1. **Samuel Dodge** and Lina Karam, *Introduction to Machine Learning and Deep Learning: A Hands-On Starter's Guide*, 2017 1st version; revised 2020. Available online at: https://deeplearningtextbook.org/
2. Lina J. Karam and **Naji Mounsef**, *Introduction to Engineering: A Starter's Guide With Hands-On Digital Multimedia Explorations and Robotics,* Morgan-Claypool, 2008.
3. Lina J. Karam and **Naji Mounsef**, *Introduction to Engineering: A Starter's Guide With Hands-On Analog Multimedia Explorations,* Morgan-Claypool, 2008.
4. Lina J. Karam, *Design of Complex Digital FIR Filters in the Chebyshev Sense*, Ph.D. Thesis, Georgia Institute of Technology, March 1995.

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1. **Vicente Molieri**, Lina J. Karam, and Zoe Lacroix, "CLAST: Clustering Biological Sequences," in Emerging Trends in Computational Biology, Bioinformatics, and Systems Biology (Q. Nam and H. Arabnia Eds.), Chapter 10, pp. 203-220, Aug. 2015, Elsevier. ISBN: 978-0-12-802508-6. http://www.sciencedirect.com/science/book/9780128025086
2. **Nabil G. Sadaka** and Lina J. Karam, "Perceptually Driven Super-Resolution Techniques," in *Perceptual Digital Imaging: Methods and Applications*, Rastislav Lukac Editor, CRC Press/Taylor & Francis, 2012.
3. Lina J. Karam, "Lossless Image Compression," *in The Essential Guide to Image Processing,* Al Bovik Editor, Chapter 16, pages 385-417, Elsevier Academic Press, 2009.
4. Lina J. Karam, "Lossless Coding", *in the Handbook of Image and Video Processing*, 2nd Edition, Al Bovik Editor, Chapter 5.1, pages 643-660, Elsevier Academic Press, 2005.
5. Umesh Rajashekar, Alan C. Bovik, Daniel Sage, Michael Unser, Lina J. Karam, and Reginald Lagendijk, "Image Processing Education," *in the Handbook of Image and Video Processing*, 2nd Edition, Al Bovik Editor, Chapter 2.4, pages 73-95, Elsevier Academic Press, 2005.
6. Lina J. Karam, "Lossless Image Coding," i*n the Handbook of Image & Video Processing* Al Bovik, Editor, Chapter 5.1, pages 461-474, Academic Press, 2000.
7. Lina J. Karam, James H. McClellan, Ivan Selesnick, and C. Sidney Burrus, "Digital Filtering," *in the Digital Signal Processing Handbook* (V. K. Madisetti and D. B. Williams, Editors), Chapter 11, pages 11-1 to 11-86, CRC Press, 1998.

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2. **Yingpeng Deng** and Lina J. Karam, "Frequency-Tuned Adversarial Attacks on Texture Recognition," *IEEE Transactions on Image Processing*, vol. 31, pp. 5856-5868, Sept. 2022.

3. **Charan D. Prakash** and Lina J. Karam, "It GAN DO Better: GAN-based Detection of Objects on Images with Varying Quality," *IEEE Transactions on Image Processing*, vol. 30, pp. 9220-9230, Nov. 2021.

4. Lina J. Karam, Jay Katupitiya, Vicente Milanés, Ioannis Pitas, and Jieping Ye, "Autonomous Driving Part 2 – Learning and Cognition," *IEEE Signal Processing Magazine*, vol. 38, no. 1, pp. 20-21, Jan. 2021.

5. Lina J. Karam, Jay Katupitiya, Vicente Milanés, Ioannis Pitas, and Jieping Ye, "Autonomous Driving Part 1 – Sensing and Perception," *IEEE Signal Processing Magazine*, vol. 37, no. 4, pp. 11-13, July 2020.

6. **Bashar M. Haddad, Samuel F. Dodge,** Lina J. Karam, Nital S. Patel, and Martin W. Braun, "Locally Adaptive Statistical Background Modeling with Deep Learning-Based False Positive Rejection for Defect Detection in Semiconductor Units," *IEEE Transactions on Semiconductor Manufacturing*, vol. 33, issue 3, pp. 357-372, Aug. 2020.

7. **Tejas S. Borkar** and Lina J. Karam, "DeepCorrect: Correcting DNN Models against Image Distortions," *IEEE Transactions on Image Processing*, vol. 28, issue 12, pp. 6022-6034, Dec. 2019.

8. **Jinane S. Monsef** and Lina J. Karam, "Augmented Sparse Representation Classifier (ASRC) for Face Recognition under Quality Distortions," *IET Biometrics Journal,* vol. 8, issue 6, pp. 431-442, Nov. 2019.

9. **Samuel F. Dodge** and Lina J. Karam, "Human and DNN Classification Performance on Images With Quality Distortions: A Comparative Study," ACM Transactions on Applied Perception, vol. 16, issue 2, 18 pages, March 2019; doi 10.1145/3306241.

10. **Charan D. Prakash**, Farshad Akhbari, and Lina J. Karam, "Robust Obstacle Detection for Advanced Driver Assistance Systems using Distortions of Inverse Perspective Mapping of a Monocular Camera," *Robotics and Autonomous Systems Journal,* vol. 114, pp. 172-186, 2019. *Note: The developed precursor real-time forward collision warning system prototype was demonstrated by our Intel industry collaborators at the 2015 Consumer Electronics Show (CES) in Las Vegas.*

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12. **Samuel F. Dodge** and Lina J. Karam, "Visual Saliency Prediction Using a Mixture of Deep Neural Networks," *IEEE Transactions on Image Processing,* vol. 27, no. 8, pp. 4080-4090, August 2018.

13. **Aditee Shrotre** and Lina J. Karam, "Full Reference Objective Quality Assessment for Reconstructed Background Images," *Journal of Imaging*, vol. 4, no. 6, 82; 24 pages, June 2018. https://doi.org/10.3390/jimaging4060082

14. **Samuel Dodge**, **Jinane Mounsef**, and Lina J. Karam, "Unconstrained Ear Recognition using Deep Neural Networks," *IET Biometrics*, 8 pages. January 2018. doi: 10.1049/iet-bmt.2017.0208

15. **Milind S. Gide** and Lina J. Karam, "Computational Visual Attention Models," *Foundations and Trends® in Signal Processing*, vol. 10, no. 4, pp 347-427, 2017. http://dx.doi.org/10.1561/2000000055 (*invited*)

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19. **Mahesh Subedar** and Lina J. Karam, "3D Blur Discrimination," *ACM Transactions on Applied Perception*, vol. 13, issue 3, article no. 12, 13 pages, May 2016, doi 10.1145/2896453.

20. **Jinjin Li**, Bonnie L. Bennett, Lina J. Karam, and Jeffrey S. Pettinato, "Stereo Vision Based Automated Solder Ball Height and Substrate Coplanarity Inspection," *IEEE Transactions on Automation Science and Engineering*, vol. 13, no. 2, pp. 757-771, April 2016.

21. **Srenivas Varadarajan** and Lina J. Karam, "A No-Reference Texture Regularity Metric Based On Visual Saliency," *IEEE Transactions on Image Processing*, vol. 24, no. 9, pp. 2784-2796, Sep. 2015.

22. **Qian Xu, Srenivas Varadarajan**, Chaitali Chakrabarti, and Lina J. Karam, "A Distributed Canny Edge Detector: Algorithm and FPGA Implementation," *IEEE Transactions on Image Processing,* pp. 2944-2960, vol. 23, no. 7, Jul. 2014.

23. **Tong Zhu** and Lina J. Karam, "A No-Reference Objective Image Quality Metric based on Perceptually Weighted Local Noise," *EURASIP Journal on Image and Video Processing*, 2014 (8 pages). Available online: http://jivp.eurasipjournals.com/content/2014/1/5.

24. **Berkay Kanberoglu**, Nina Z. Moore, David Frakes, Lina J. Karam, Josef P. Debbins, Mark C. Preul, "Neuronavigation using Three-Dimensional Proton Magnetic Resonance Spectroscopy Data," *Stereotactic and Functional Neurosurgery*, pp. 306-314, 92(5), 2014.

25. **Sin Lin Wu**, Jorge Caviedes, Lina Karam, and Ingrid Heynderickx, "The Effect of Applying 2D Enhancement Algorithms on 3D Video Content," *Hindawi Journal of Electrical and Computer Engineering*, 11 pages, 2014. Online at: http://dx.doi.org/10.1155/2014/601392.

26. **Akshay Pulipaka**, Patrick Seeling, Martin Reisslein, and Lina J. Karam, "Traffic and Statistical Multiplexing Characterization of 3-D Video Representation Formats," *IEEE Transactions on Broadcasting*, 59(2), pp. 382-389, June 2013.

27. Lina J. Karam, W. Bastiaan Kleijn, and Karon MacLean, "Perception-based Media Processing," *Proceedings of the IEEE*, 101(9), pp. 1900-1904, Sept. 2013.

28. **Asaad Said**, Bonnie Bennett, Lina Karam, Alvin Siah, Kyle Goodman, and Jeffrey Pettinato, "Automated Void Detection in Solder Balls in the Presence of Vias and Other Artifacts," *IEEE Transactions on Electronics Packaging Manufacturing*, vol. 2, no. 11, pp. 1890-1901, November 2012. *Note: The developed void detection technology helped in enabling two industry standards, JEDEC JC 14-1 void guideline and IPC-7095C.*

29. **Rohan Gupta**, **Akshay Pulipaka**, Patrick Seeling, Lina J. Karam, and Martin Reisslein, "H.264 Coarse Grain Scalable (CGS) and Medium Grain Scalable (MGS) Encoded Video: A Trace Based Traffic and Quality Evaluation," *IEEE Transactions on Broadcasting*, vol. 58, no. 3, pp. 428 to 439, September 2012.

30. Gaurav Sharma, Lina Karam, and Patrick Wolfe, "Select Trends in Image, Video, and Multidimensional Signal Processing," *IEEE Signal Processing Magazine*, pp. 5-8, Jan. 2012.

31. Lina J. Karam, **Nabil G. Sadaka, Rony Ferzli and Zoran A. Ivanovski**, "An Efficient Selective Perceptual-Based Super-Resolution Estimator," *IEEE Transactions on Image Processing*, vol. 20, no. 12, pp. 3470-3482, Dec. 2011.

32. Touradj Ebrahimi, Lina Karam, Fernando Pereira, Khaled El-Maleh, and Ian Burnett, "The Quality of Multimedia: Challenges and Trends," *IEEE Signal Processing Magazine*, pp. 17 & 148, Nov. 2011.

33. **Shyamprasad Chikkerur**, **Vijay Sundaram,** Martin Reisslein, and Lina J. Karam, "Objective Video Quality Assessment Methods: A Classification, Review, and Performance Comparison," *IEEE Transactions on Broadcasting*, vol. 57, no. 2, pp. 165-182, June 2011.

34. **Niranjan D. Narvekar** and Lina J. Karam, "A No-Reference Image Blur Metric Based on the Cumulative Probability of Blur Detection (CPBD)," *IEEE Transactions on Image Processing*, vol. 20, no. 9, pp. 2678-2682, Sep. 2011.

35. **Asaad F. Said**, Bonnie L. Bennett, Lina J. Karam, and Jeff Pettinato, "Automated Detection and Classification of Non-Wet Solder Joints," *IEEE Transactions on Automation Science and Engineering,* vol. 8, no. 1, pp. 67-80, Jan. 2011. *Note: The developed non-wet solder joints detection technology was granted a Divisional Recognition Award by Intel.*

36. **Asaad F. Said**, Bonnie L. Bennett, Lina J. Karam, and Jeff Pettinato, "Robust Automated Void Detection in Solder Balls and Joints," *OnBoard Technology Magazine*, *Issue of the Decade on Quality*, pp. 36-41, Sep. 2010.

37. **Wei-Jung Chien** and Lina J. Karam, "Transform-Domain Distributed Video Coding with Rate-Distortion Based Adaptive Quantization," *IET Image Processing Journal, Special Issue on Distributed Video Coding,* pages 340-354, vol. 3, no. 6, December 2009.

38. Lina J. Karam, **Ismail AlKamal**, Alan Gatherer, Gene Frantz, David Anderson, and Brian Evans, "Trends in Multi-Core DSP Platforms," *IEEE Signal Processing Magazine, Special Issue on Signal Processing on Platforms with Multiple Cores*, pages 38-49, November 2009.

39. **Wei-Jung Chien** and Lina J. Karam, "BLAST-DVC: BitpLAne SelecTive Distributed Video Coding," *Springer Multimedia Tools and Applications Journal, Special Issue on Distributed Video Coding*, 20 pages, July 2009, DOI 10.1007/s11042-009-0314-8; pp. 437-456, 2010.

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41. **Rony Ferzli** and Lina J. Karam, "A No-Reference Objective Image Sharpness Metric Based on the Notion of Just Noticeable Blur (JNB)," *IEEE Transactions on Image Processing*, vol. 18, no. 4, pp. 717-728, April 2009.

42. **Brian Lenoski**, Leslie C. Baxter, Lina J. Karam, José Maisog, and Josef Debbins, "On the Performance of Autocorrelation Estimation Algorithms for fMRI Analysis," *IEEE Journal on Special Topics in Signal Processing, Special Issue on Functional Magnetic Resonance Imaging*, vol. 2, no. 6, pp. 828-838, Dec. 2008.

43. **Geert Van der Auwera**, **Prasanth T. David**, Martin Reisslein, and Lina J. Karam, "Traffic and Quality Characterization of the H.264/AVC Scalable Video Coding Extension," *Advances in Multimedia*, vol. 2008, Article ID 164027, 27 pages, 2008. doi:10.1155/2008/164027.

44. Andrew B. Watson, **Zhen Liu**, and Lina J. Karam, "JPEG2000 Encoding with Perceptual Distortion Control," *NASA Tech Brief*, pp. 37-38, Sep. 2008.

45. **Geert Van der Auwera**, Martin Reisslein, and Lina J. Karam, “Corrections to “Video Texture and Motion Based Modeling of Rate Variability-Distortion (VD) Curves,” *IEEE Transactions on Broadcasting*, vol. 54, no. 1, pp. 166 – 166, Mar. 2008.

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47. **Geert Van der Auwera**, Martin Reisslein, and Lina J. Karam, “Corrections to “Video Texture and Motion Based Modeling of Rate Variability-Distortion (VD) Curves,” *IEEE Transactions on Broadcasting*, vol. 53, issue 4, pp. 811 – 811, Dec. 2007.

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49. **Zhen Liu**, Lina J. Karam, and Andrew B. Watson, “JPEG2000 Encoding with Perceptual Distortion Control,” *IEEE Transactions on Image Processing*, vol. 15, no. 7, pp. 1763-1778, Jul. 2006.

50. **Zhen Liu** and Lina J. Karam, “Mutual Information-Based Analysis of JPEG2000 Contexts,” *IEEE Transactions on Image Processing*, vol. 14, no. 4, pp. 411-422, April 2005.

51. Glen P. Abousleman, **Tuyet-Trang Lam**, and Lina J. Karam, “Robust Hyperspectral Image Coding with Channel-Optimized Trellis-Coded Quantization,” *IEEE Transactions on Geoscience and Remote Sensing*, vol 40, no. 4, pp. 820-830, April 2002.

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53. **M. Yassin Hasan**, Lina J. Karam, Matt Falkinburg, Art Helwig, and Matt Ronning, "Canonic Signed Digit Digital Filter Design," *IEEE Signal Processing Letters*, vol. 8, pp. 167-169, June 2001.

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55. **Ingo Höntsch** and Lina J. Karam, "Locally Adaptive Perceptual Image Coding," *IEEE Transactions on Image Processing*, vol. 9, pages 1472-1483, Sept. 2000.

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62. Lina J. Karam and James H. McClellan, "Complex Chebyshev Approximation for FIR Digital Filter Design," *IEEE Transactions on Circuits and Systems II*, vol. 42, pp. 207-216, March 1995.

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4. **Tejas Borkar,** Felix Heide, and Lina J. Karam, "Defending Against Universal Attacks through Selective Feature Regeneration," *IEEE Conference on Computer Vision and Patten Recognition (CVPR),* 11 pages, June 2020.

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Thesis Title: Performance Evaluation of Object Proposal Generators for Salient Object Detection
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Vinay KashyapTakmulPurushothamaRaju
Date: December 2014
Thesis Title: Fisheye Camera Calibration and Applications
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Tejas Borkar
Date: December 2013
Thesis Title: Automated Animal Coloration Quantification in Digital Images using Colors and Skin Classification
Affiliation: received Ph.D. at ASU (under my supervision); Motional, Tempe, AZ (current)

Charan Prakash
Date: Spring 2012
Thesis Title: Camera Calibration using Adaptive Segmentation and Ellipse Fitting for Localizing Control Points
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Nicholas Werth
Date: February 2011
Thesis Title: Synthetic Aperture Radar Image Formation via Sparse Decomposition
Affiliation: Lockheed Martin

Vijay Sundaram
Date: September 2010
Thesis Title: Fast Algorithms and Architectures for High Throughput Encoding in H.264/AVC
(Co-advised with Dr. Chaitali Chakrabarti)
Affiliation: Dolby Laboratories, USA; prebiously with Intel, Portland, OR
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Adithya Murthy

Date: May 2010
Thesis Title: Matlab Based Framework for Image and Video Quality Evaluation
Affiliation: Intel, Chandler, AZ ; Qualcomm, San Diego, CA (current)

Vicente Molieri
Date: April 2010
Thesis Title: Genomic Sequence Clustering

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Date: July 2009
Thesis Title: Real-Time Fixed-Point Wavelet-Based Image Compression
Affiliation: General Dynamics Decision Systems, AZ; Fujitsu, AZ; Intel, AZ; CoreKinect, AZ (current)
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Manal Jalloul
Date: June 2009 (American University of Beirut)
Thesis Title: Improving Side Information Generation in a Distributed Video Coding System
(Co-advised with Prof. M. Adnan Al-Alaoui at the American University of Beirut)
Affiliation: Co-Founder, AI Lab, Lebanon (current); Lecturer, AUB and LAU, Lebanon (current)

Berkay Kanberoglu
Date: December 2008
Thesis Title: Novel Tools and Techniques in Neurosurgical Planning
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Brian Lenoski
Date: May 2007
Thesis Title: Estimating the Autocorrelation of Functional Magnetic Resonance Imaging: Presurgical Mapping of Finger Movement and Reading Comprehension
Affiliation: Medical Numerics, Germantown, MD; Apple, USA; Modsy, USA (current)
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Houssam Abbas
Date: May 2006
Thesis Title: Analysis and Suppression of Mosquito Noise in Compressed Video using Optimized Epsilon-Filters
Affiliation: Intel, Chandler, AZ; Pursued PhD in CS at ASU; Postdoc at University of Pennsylvania; Assistant Professor, Oregon State University, USA (current)
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Juan Andrade Rodas

Date: July 2005
Thesis Title: Semi-Autonomous 3D Tracking
Affiliation: Professor and Director, School of Electronics and Telecommunications Engineering, University of Cuenca, Cuenca, Ecuador; Pursued PhD at ASU

Mahesh Subedar
Date: May 2004
Thesis Title: Scalable Embedded Region-Of-Interest based Image Coding
Affiliation: Intel, Chandler, AZ; Pursued PhD at ASU; Intel Labs, USA (current)

Muhammad Yasin
Date: December 2003
Thesis Title: Web-Based Two-Dimensional Signal Processing

Katherine Tyldesley
Date: May 2003
Thesis Title: Wireless Video Coding and Transmission over the Iridium Network
Affiliation: IBM, Tucson, AZ

Charles Q. Zhan
Date: May 2003
Thesis Title: Adaptive Wavelet-Based Image Denoising with Edge Preservation
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Lei Gao
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Thesis Title: Error-Resilient Image Coding and Transmission over Wireless Channels
Affiliation: Engineering Manager, General Electric – Aviation, USA; previously with Honeywell, Phoenix, AZ
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David Giguet
Date: December 2001
Thesis Title: Error-Resilient and Very Low Bit Rate Image Coding
Affiliation: Renault Software Labs, France; previously with Purple Labs, Chambery, France; SAGEMCOM, France; Avaya, France; Intel, France
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Sumohana Channappayya
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Thesis Title: Error-Resilient Image Coding and Transmission
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Mohamad Owais Osmani
Date: December 1999
Thesis Title: Object-based Processing
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Date: August 1999
Thesis Title: Image Compression for Noisy Environments
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INSTRUCTION

New Courses Developed

1. EEE 598 Deep Learning for Media Processing and Understanding (developed in Spring 2018 and offered yearly)

This is a four-credit graduate-level course that covers the fundamentals of deep learning with applications to media classification, processing, restoration, compression, and generation. Examples of media include image, video, text, speech, and audio. This course also includes hands-on assignments and projects in Python.
Some of the topics covered include:

- Basic Concepts in Machine Learning
- Probability Basics
- Motivation for Deep Learning
- Deep Feedforward Networks
- Regularization for Deep Learning
- Optimization for Training Deep Models
- Recurrent and Recursive Nets
- Autoencoders, Generative Models, Generative Adversarial Networks
- Applications: Computer Vision, Image Generation, Image Compression, Video Processing, Natural Language Processing

2. EEE 508 Digital Image and Video Processing and Compression

This is a four-credit graduate-level course that covers the fundamentals of digital image perception, representation, processing, and compression and include hands-on assigenemnts and projects in OpenCV/C/C++, Matlab, and Android Studio. Some of the topics covered include:

- Two-Dimensional Digital Signal Processing Basics
- Vision and Perception
- Light and Color Models
- Image Segmentation
- Image Enhancement
- Image Restoration

- Basic Concepts in Information Theory
- Scalar and Vector Quantization
- Rate Distortion Theory
- Image Transforms
- Predictive, Transform, and Subband Coding
- Motion Estimation
- Entropy Coding: Huffman and Arithmetic Coding
- Run-Length Coding
- JPEG and JPEG2000 Image Compression Standards
- Motion Estimation and Compensation
- ISO MPEG and ITU-T VCEG Video Compression Standards

3. EEE 507 Multidimensional Signal Processing

This is a three-credit graduate-level course that is concerned with understanding signals of more than one variable and with systems for processing them. The specific topics covered are:

- Multi-D Discrete-Time(Space) Signals and Systems
- Multi-D Sampling
- Multi-D Discrete Fourier Transform (DFT)
- Multi-D Finite Impulse Response (FIR) Digital Filters
- Multi-D Z-Transform
- Multi-D Infinite Impulse Response (IIR) Digital Filters
- Processing of Propagating Space-Time Signals
- Multi-D Signal Restoration and Reconstruction
- Medical Imaging

4. EEE 404/EEE 591 Real-Time Digital Signal Processing

This is a four-credit senior-level course that provides the students with knowledge and hands-on experience in translating DSP concepts into real-time software for embedded systems using fixed-point DSP boards (Freescale DSP56858 and TI TMS320C5510). In addition to two 75-minute lecture sessions per week, on-campus students meet weekly for a three-hour laboratory session under the guidance of a TA. On-line students can access and control the lab equipment, boards, and software remotely, and can develop and run real-time applications from their remote location using the lab equipment, hardware, and software through a user-friendly "virtual bench" interface. I secured funding for the development of this course from the Consortium for Embedded and Inter-Networking Technologies (CEINT), Motorola, Freescale, Texas Instruments, and Tektronix.

The lecture topics covered include:

- Real-Time Systems: Introduction and Basics
- Basic Concepts in Signals and Systems: signals, Analog-to-Digital/Digital-to-Analog conversion, sampling and aliasing, quantization, discrete-time representation, filtering
- Digital Signal Processor Architectures: Harvard architecture, special addressing modes, parallel instructions, pipelining, real-time programming, modern digital signal processor architectures, hardware interfacing
- Computer Arithmetic: fixed-point and floating-point numbers, integer arithmetic

- Finite-wordlength effects: quantization, overflow, saturation, scaling, rounding and truncation
- Fixed-point Digital Signal Processors
- Fast Fourier Transforms and Applications: DTFT, DFT, FFT, implementation complexity, linear convolution, circular convolution, fast convolution, Short-Time Fourier Transform and Spectogram
- Real-Time Multimedia and Communication Applications: speech processing, and/or audio processing , and/or image processing, and/or adaptive filtering, and/or modulation/demodulation, and/or matched filtering, and/or equalization.

The labs include:

- Lab 1: Overview of Hardware and Software Tools.
- Lab 2: Introduction to CodeWarrior.
- Lab 3: Introduction to the DSP56800E Assembly.
- Lab 4: Introduction to On-Chip Peripherals.
- Lab 5: Introduction to Processor Expert.
- Lab 6: Applications Using the DSP56858EVM CODEC.
- Lab 7: Real-Time Image Processing.
- Lab 8: Introduction to Code Composer Studio and TMS320C55x Assembly.
- Lab 9: Musical Notes Synthesis
- Lab 10: Introduction to On-Chip Peripherals and Music Equalizer
- Lab 11: Fast Fourier Transform
- Lab 12: Applications of Fast Fourier Transform (Spectrum Analysis and Speech Processing)
- Lab 13: Modem (optional)

5. **EEE/CSE/FSE 101 Introduction to Engineering Design**

This is a Freshman level course which was developed to include two 50-minute lectures per week and a 2-hour hands-on lab session per week under the supervision of a TA. In addition, the students work in teams on two 4-week projects (one of which is a Robotics project) that build on the lab experiments. I secured funding for the development of this course from National Instruments (cash and equipment in the amount of $120,000). The lecture component of this course was adapted from the previously taught ECE100 (Intro to Engineering Design) course. The lab component was fully developed from scratch as it was non-existent in the previous ECE100 course. The laboratory component of this course was designed to include hands-on lab experiments that expose entering freshman students to a wide range of areas in electrical and computer engineering including circuits, electronics, communications, analog and digital signal processing, digital image processing, computing hardware and software, embedded systems, robotics and control.

The developed labs include:

- Lab 1: Introduction to Circuits: NI ELVIS, Breadboard, Circuit elements
- Lab 2: Analog Audio Level Meter (using comparators)
- Lab 3: Noise Removal Using Analog Filters
- Lab 3: Analog Music Equalizer (using op-amps)
- Lab 4: Analog Music Composer (using 555 timers)
- Lab 5: Introduction to LabVIEW and SPEEDY-33

- Lab 6: Digital Audio Level Meter
- Lab 7: Noise Removal using Digital Filters
- Lab 8: Digital Music Equalizer
- Lab 9: Digital Music Composer
- Lab 10: Digital Sound Effects
- Lab 11: Introduction to Robotics
- Lab 12: Digital Image Processing Basics
- Lab 13: Webcam Applications
- Lab 14: Telephone
- Lab 15: Amplitude Modulation
- Lab 16: Modem